B^0/B^+ Meson Lifetimes using Semileptonic Decays in CDF Run II

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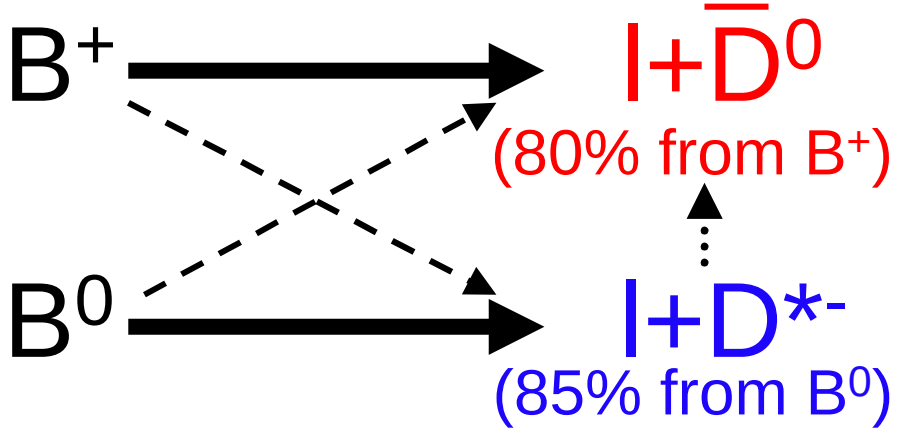
Lifetime with Semileptonics

- Heavy Quark Expansion model predict the lifetimes for different B hadron species
  - $\tau(B_c) << \tau(\Xi_b^0) \sim \tau(\Lambda_b)$
    $< \tau(B^0) \sim \tau(B_s) < \tau(B^-)$
    $< \tau(\Xi_b^-) < t(\Omega_b)$
  - $\tau(B^+)/\tau(B^0)$
    $= 1.00 + 0.05 \times (f_B/200\ \text{MeV})^2$
  - $\tau(B_s)/\tau(B^0) = 1.00 \pm 0.01$
  - $\tau(\Lambda_b)/\tau(B^0) \sim 0.9$

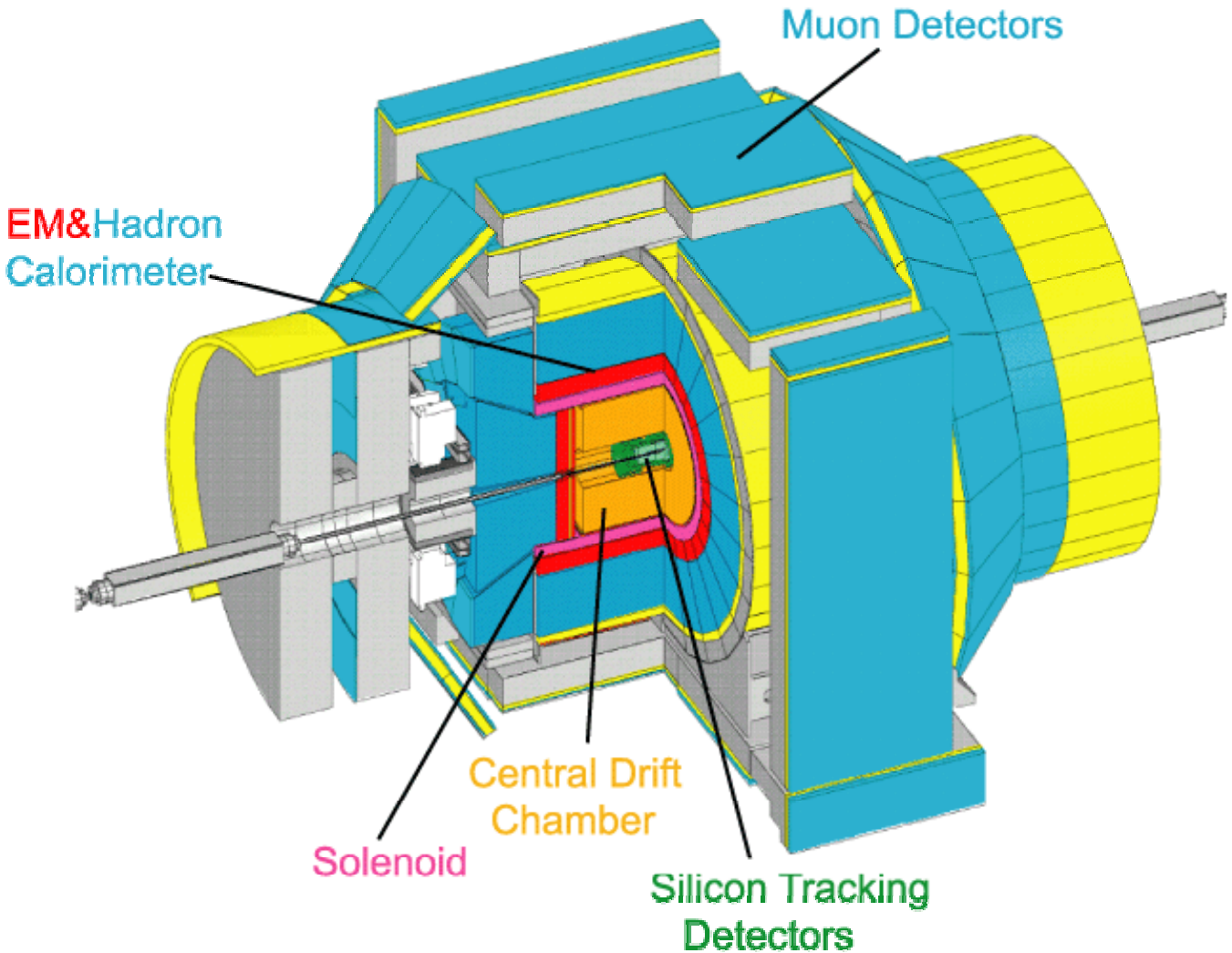
It will be a good test for the HQE to measure these values directly



To measure B^0/B^+ lifetime,

1. $l+D^0$ sample;
   fit $B^{0/+}$ average lifetime
2. $l+D^{*-}$ sample; fit B^0 lifetime
3. $l+D^0$ sample(D^{*-} excluded);
   fit B^+ lifetime
4. Get B^+/B^0 lifetime ratio

The CDF-II Detector



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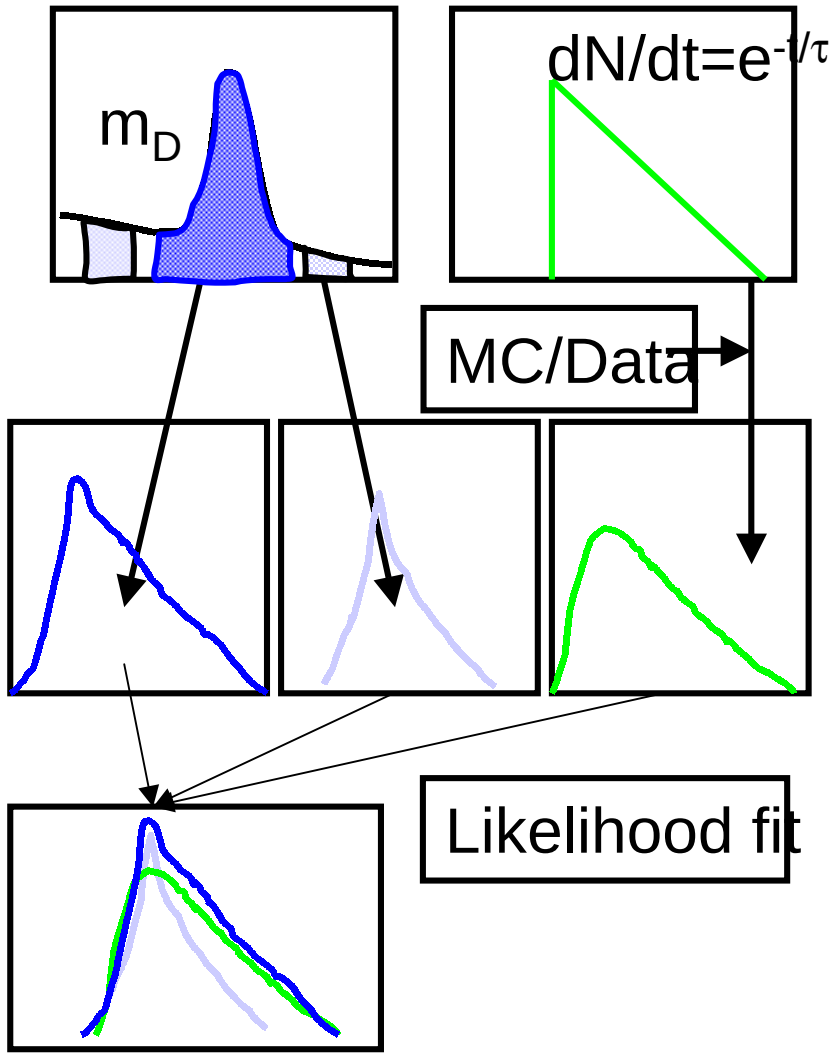
Analysis overview

- (1) Reconstruct μ+D^0 signal
  - Divide D^0 and D* candidates
  - Estimate sample composition
- (2) Calculate decay time
- (3) Estimate background
  - Use D^0 mass sideband
- (4) Estimate the bias to the decay time distribution
  - K factor
  - SVT impact parameter cut
  - Resolution smearing
- (5) Extract the lifetime
  - Unbinned likelihood fit



μ+D^0 sample

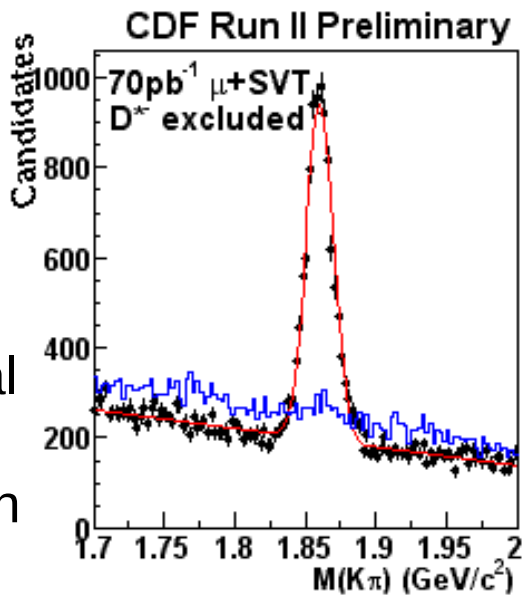
- **Data is from μ+SVT dataset**

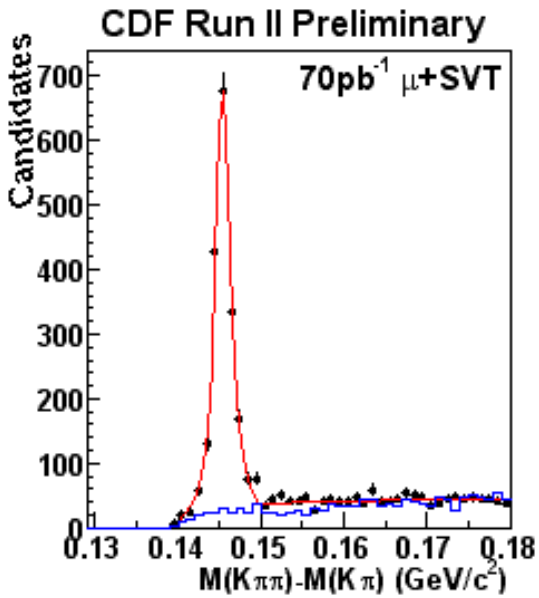
  SVT…Silicon Vertex Tracker measures impact parameter at the trigger level
- **Lepton+SVT trigger**
  - Require 4 GeV lepton + 2 GeV SVT track (=charm daughter track) which have $120\ \mu m < |d_0^{SVT}| < 1\ mm$
  - Efficiently collect semileptonic B decay signal
  - SVT impact parameter cut biases B lifetime distribution

- **Signal Reconstruction**

  Reconstruct $\overline{D}^0 \to K^+ \pi^-$ around the μ, then divide candidates into D^0 and D^{*-} sample
  - $B^{0/+} \to \mu^+ \nu \overline{D}^0 X$, $\overline{D}^0 \to K^+ \pi^-$ (D^{*-} excluded)
  - $B^{0/+} \to \mu^+ \nu D^{*-} X$, $D^{*-} \to \overline{D}^0 \pi$, $\overline{D}^0 \to K^+ \pi^-$

  μ and K have charge correlation
  - $Q_l = Q_K$: Right sign (black points)
  - Q_l != Q_K: Wrong sign (blue histogram)





Missing momentum (K factor)

- Real decay time

  $ct = L_B m_B / p_B$

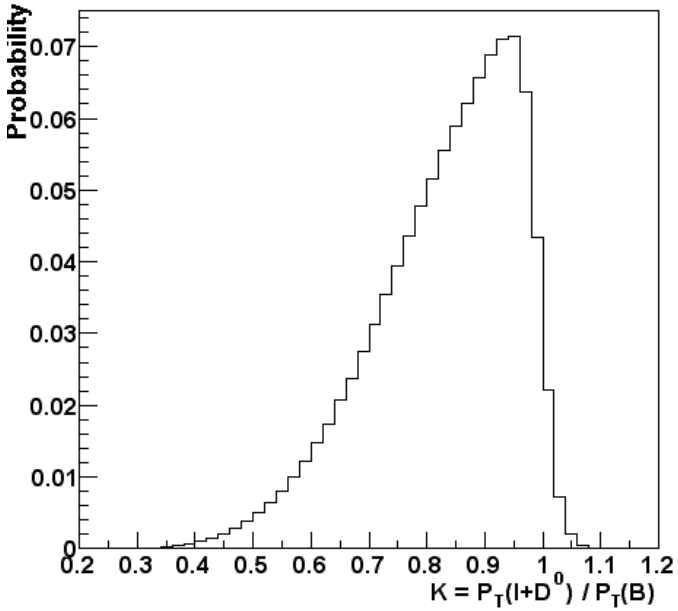
- B isn't fully reconstructed
  - We can't measure p_B but p_{lD}

    $ct = L_B m_B / p_B$

    $= L_B m_B / p_{lD} \cdot K$

    $= ct^* \cdot K$

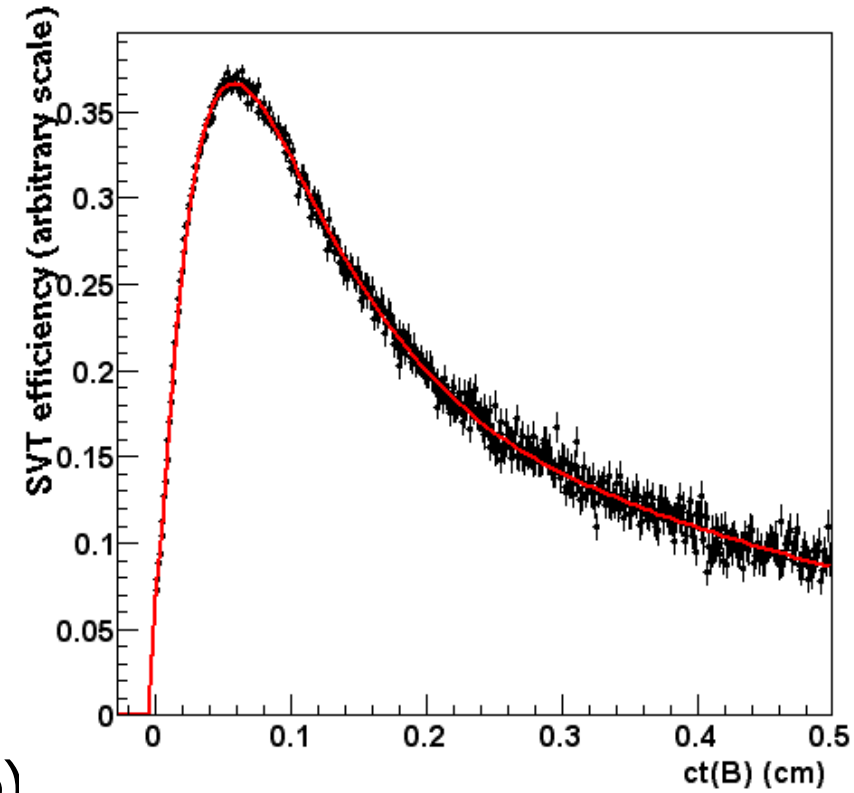
    ct^* … pseudo decay time
  - Estimate $K = p_{lD}/p_B$ from MC



- K factor depends on
  - Generated p_{TB} distribution
  - Sample composition
  - Decay model
  - Trigger/offline cuts

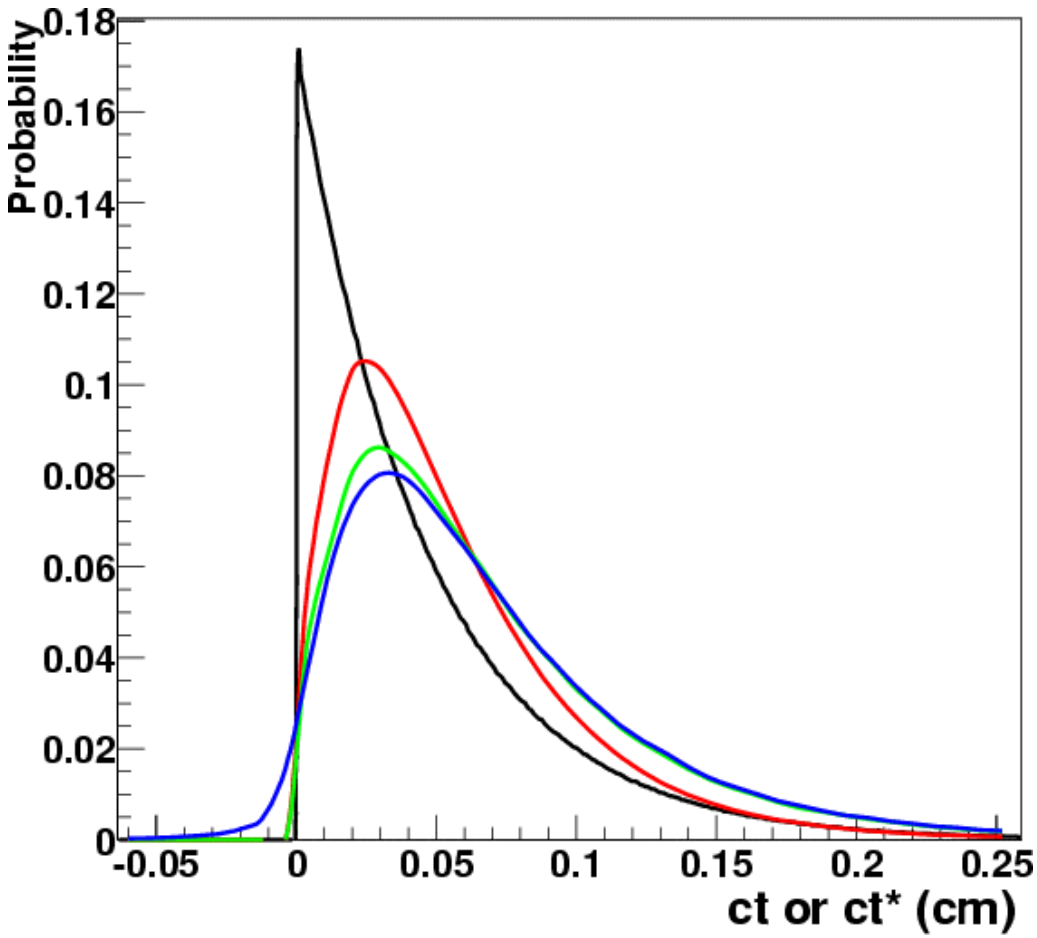
Bias from the SVT d_0 cut

- Decay time distribution
  - $dN/dt = e^{(-t/\tau)}$
- SVT impact parameter cut
  - $120\ \mu m \leq |d_0^{SVT}| \leq 1\ mm$
  - Changes the distribution
  - $dN/dt = e^{(-t/\tau)}$ x eff(t)
  - Estimate this efficiency curve from MC
- SVT bias depends on
  - Decay kinematics (e.g. $p_T, \Delta\phi$)
  - SVT tracking efficiency
  - SVT impact parameter resolution



Lifetime fitting (Unbinned likelihood fit)

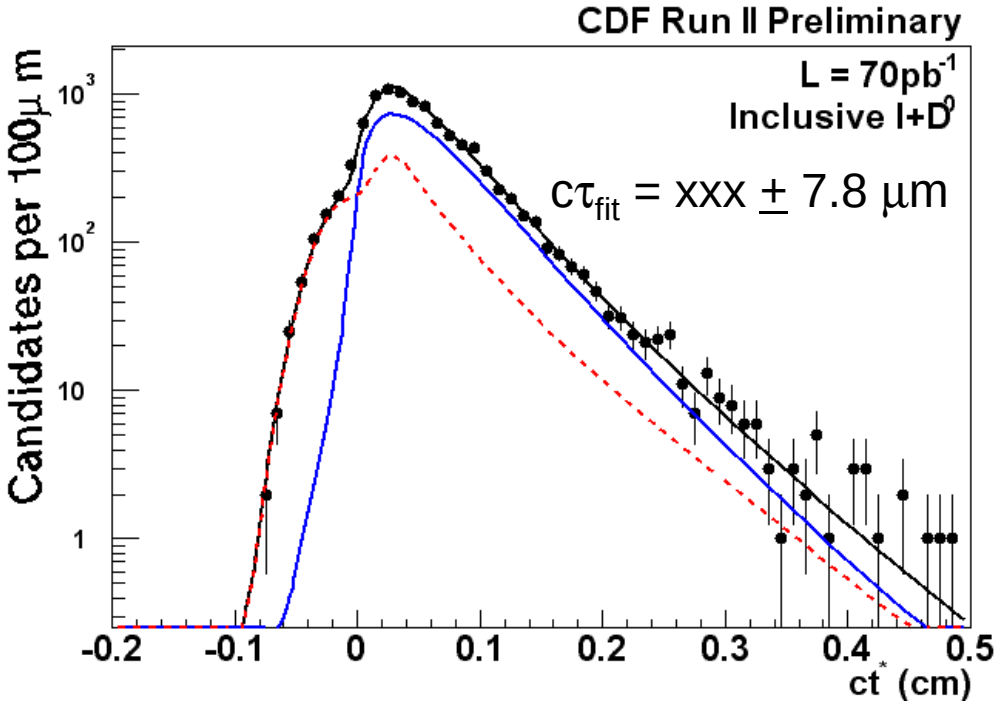
- Signal Likelihood
  - $L(t',\sigma t';\tau) = e^{(-t/\tau)}$
  - $\times$ eff(t)
  - $\otimes$ D(K)
  - $\otimes$ R(t',t; $\sigma_{t'}$)
- Likelihood distribution
  - Physics (exponential)
  - Apply SVT efficiency
  - Apply K factor
  - Apply resolution function



Fitting Results (inclusive l+D^0)

- Fitting result shows statistically significant difference with the world average
- It looks there are some systematic effects from unknown sources
- For now we will not show any fitted lifetime from semileptonics

  (not only $B^{0/+}$, but also B_s,Λ_b)



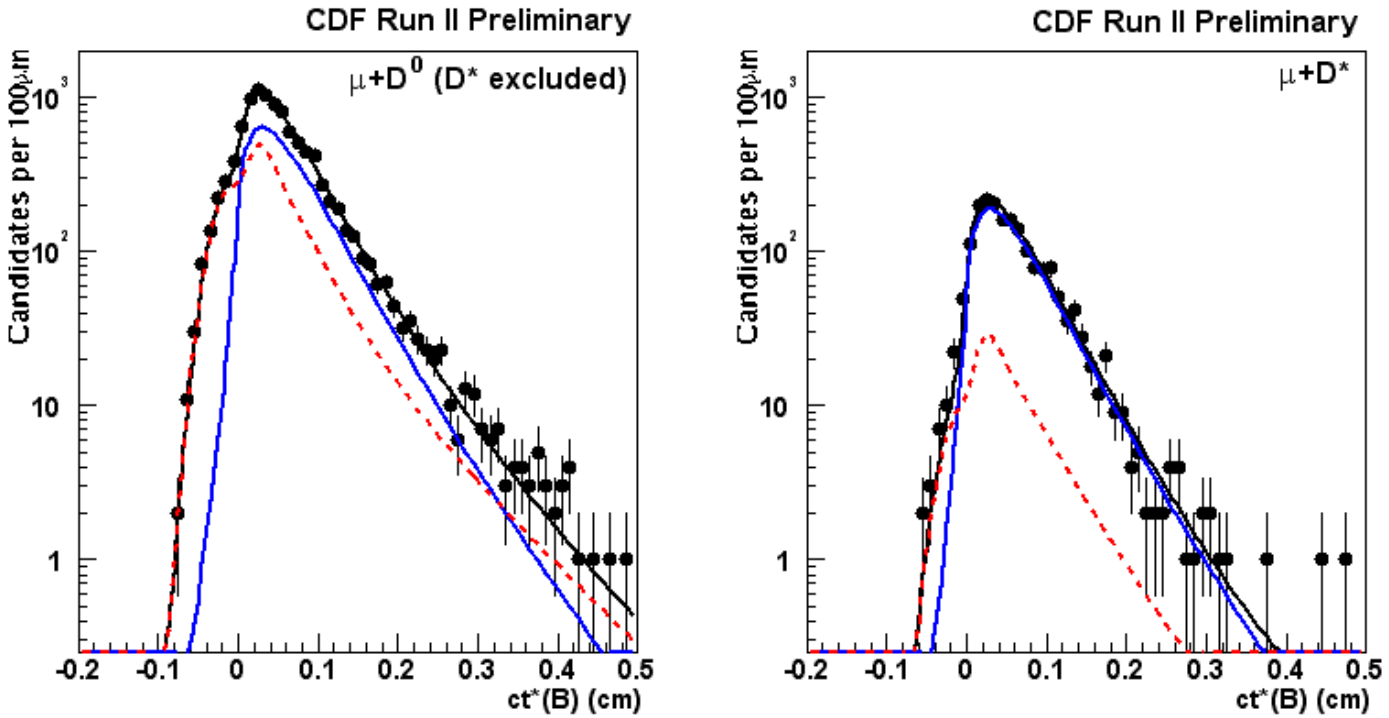
Points : data

Blue : signal likelihood

Red : background likelihood

Black : signal + background

Fitting Results(separating μ+D^0/D*)



- $c\tau(B^0)$: xxx $\pm$ 17.3 μm
- $c\tau(B^+)$: xxx $\pm$ 13.5 μm
- $c\tau(B^+) / c\tau(B^0)$: xxx $\pm$ 0.066

Summary

- We are measuring B^0/B^+ lifetimes using the semileptonic decays in CDF Run II
- We have large and clean sample (~8K each for both e,μ+$D^{0)}$ in ~ 70 pb^{-1} of the data
- There are some important issues for measuring lifetime
  - Correct for the missing momentum (K factor)
  - Correct for the bias from the SVT impact parameter cut
- Studies are ongoing for the precise B lifetime measurement